Dalitz, conversion photon, and electron measurement

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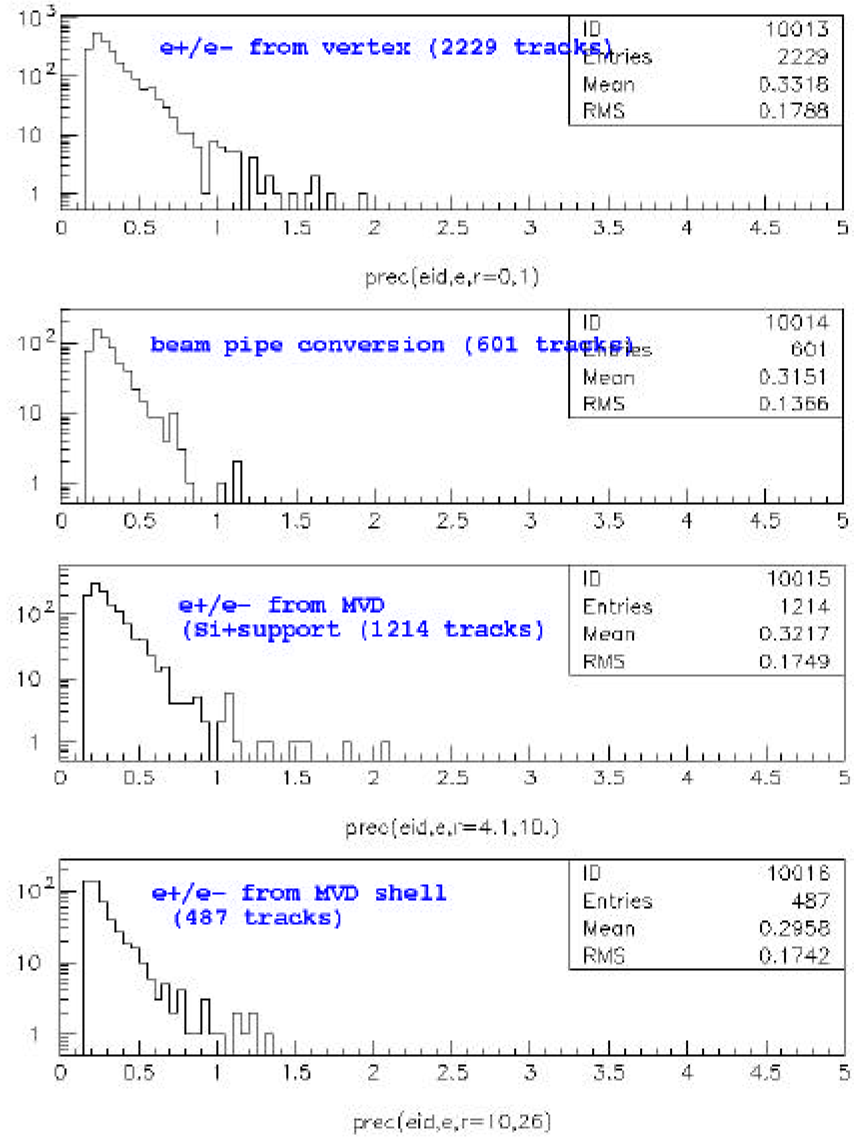
Dalitz/conversion photon as a tool

- Measurement of photon conversion and Dalitz pairs are important since
  - They are major background of electron measurement
  - They can be used to to determine the inclusive photon production
  - They can be used as a source of identified electrons that are used
    - To optimize electron ID method
    - To evaluate the electron ID efficiency
- Once we understand electrons from photon conversion and Dalitz decays, we can attack more interesting problems such as measurement of “direct electrons” from charm decays, measurement of inclusive photons, and of course, measurement of di-electron pairs.

How many electrons in PHENIX

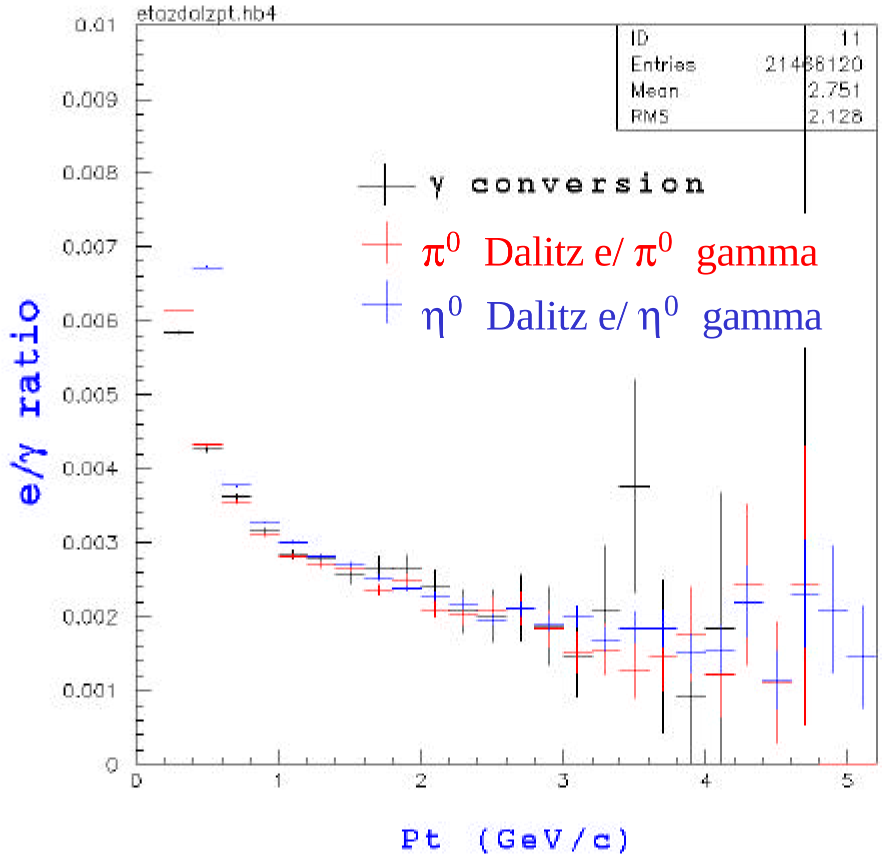
- The figures in the left side are old results of PISA simulation. They showed e+/e- spectra measured in central arms in 4342 central Au+Au events.
- There are significant number of electrons in an event:
  - 1.04 per central event (all)
  - 0.51/event from Dalitz
  - 0.14/event from beam pipe
  - 0.28/event from MVD
  - 0.11/event from MVD shell



Electron from internal/external conversion

- π^0 Dalitz, h Dalitz, and γ conversions are major sources of electrons.
- Since the decay kinematics of those 3 processes are similar, the ratio e/γ in pt>1 GeV/c is almost identical, regardless of the source.
- This means that if we know the radiation length of the beam pipe and MVD, and also know the inclusive cross section of photons, we can in principle determine electrons from those three "trivial" sources.
- Dalitz/conversion measurement can determine photon cross section as well as conversion rate directly from the data.

e/γ ratios from
external conversion (normalized)
and π^0 and η Dalitz decays



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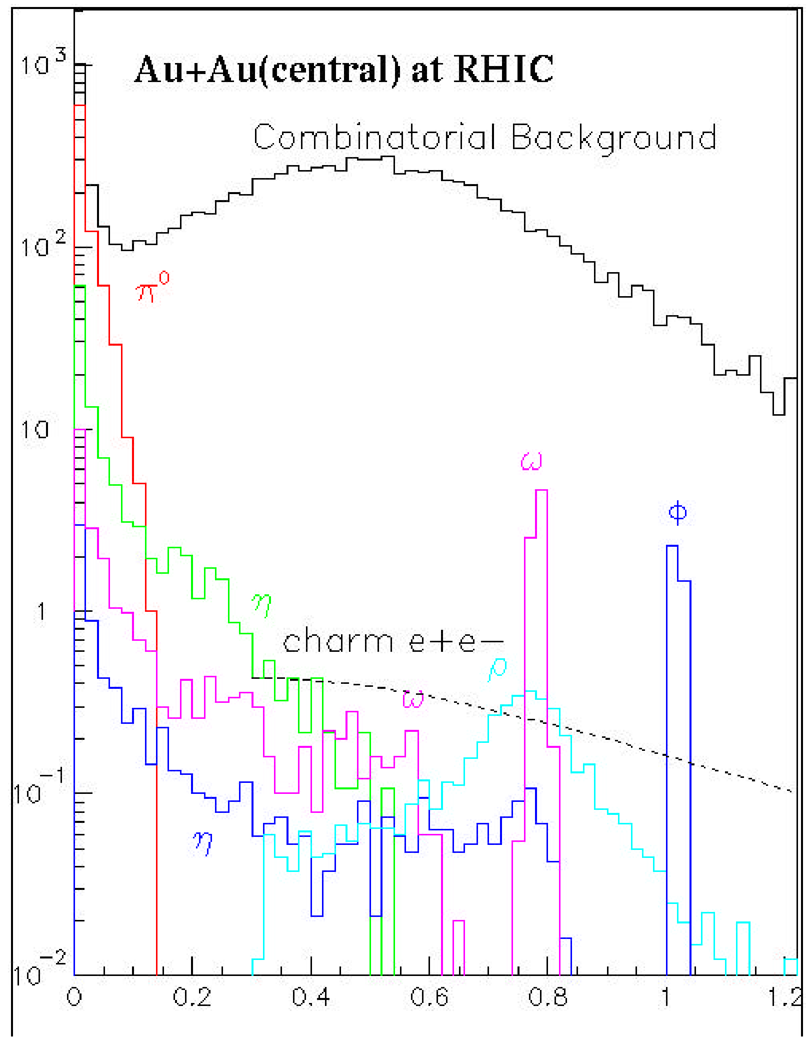
Can we measure Datliz and/or conversion?

- Answer: In the ideal world, Yes.
- The left figure shows expected mass spectrum detected by an ideal PHENIX central arms in central Au+Au collisions. Several sources of dileptons as well as the combinatorial e+e- pair background are shown.
- At very low mass region (M<100 MeV), a peak from π^0 Dalitz and gamma conversion should be visible above combinatorial background.
- Dalitz/ conversion measurement in peripheral events should be much easier because of smaller combinatorial background.



Mee

Utilities of Dalitz/conversion peak

- The S/B ratio of the Dalitz / conversion peak is very large (>>10), even in central Au+Au collisions.
- The electron ID criteria can be relaxed for Dalitz / conversion peak, since the S/B of the mass peak itself is very large
- The shape of the mass distribution can, in principle, be measured.
- The yield of the Dalitz / conversion pair in PHENIX is about 0.01 pairs per central collisions, or a few 100 K in the first year.
- The Dalitz/ conversoin peak provides a clean sample of electrons in the data, which can be used to
  - determine the detector response for the electron
  - optimize eID method and selection criteria
  - evaluate the purity of electron candidates
  - evaluate eID efficiency
- The peak can be used to measure inclusive photons.
  - Complementary to the photon measurement by the EMCAL
  - Better momentum resolution than EMCAL
  - Not suffered by the background from the magnet yoke.

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Shape of the mass distribution

- Dalitz decays (P = π^0 or η)

$$\frac{d\Gamma(P \to eeg)}{dm^2 \cdot \Gamma(P \to gg)} = \frac{2a}{3p}\sqrt{1-\frac{4m_e^2}{m^2}}(1+2\frac{m_e^2}{m^2})\frac{1}{m^2}(1-\frac{m^2}{m_P^2})^3 \left|F_P(m^2)\right|^2,$$

which can be decomposed as:

2	$\frac{a}{3p}\sqrt{1-\frac{4m_e^2}{m^2}}(1+2\frac{m_e^2}{m^2})\frac{1}{m^2}$	$(1-\frac{m^2}{m_P^2})^3$	$\left\|F_P(m^2)\right\|^2$
2 γ	QED matrix element	final state phase space	hadronic form factor

- The form factor is 1.0 at low m^2. This means that the internal conversion rate of photon is the same for π^0 and η, if m^2 is limited to small value.
- The conversion rate is

  0.23 % for m < 5 MeV

  0.33 % for m < 10 MeV

  0.44 % for m < 20 MeV

  0.50 % for m < 30 MeV

  for both of π^0 and η.
- At higher mass, conversion rate of π^0 and η become different due to the phase space factor. In 30 < m < 135 MeV, 0.1% for π^0, and 0.22% for η. This difference can, in principle, be used to constrain π^0 /η ratio(?). Note that the reconstruction efficiency can be cancelled out in comparison of the lower mass region and the higher mass region.

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Shape of mass distribution(2)

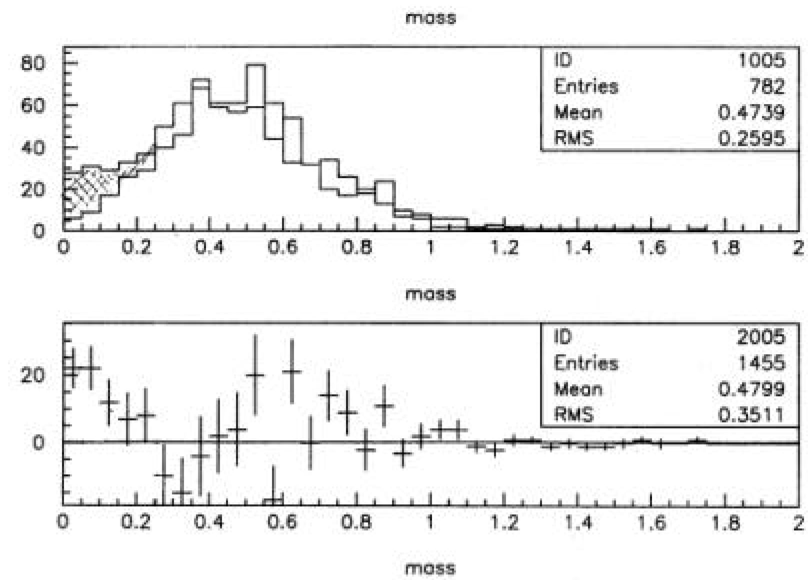
- The analytic form of the mass distribution of external conversion is more complicated, and it is limited to lower mass region. But in practice the analytic form is not relevant for PHENIX, as it is strongly subject to the detector effect, as it is explained later.
- The shape of the mass distribution of the conversion pair should be determined by Monte Carlo and from the data in low multiplicity events.
- The detector effect, such as mass resolution, on the measured mass distribution have to be evaluated for the internal as well as the external pairs

Some speculation:

- The shape of mass distribution of “internal conversion” of direct photon, if it exists, should be that of QED matrix element. This factor should be universal irrespective to the mechanism how photon is generated. Or is there some medium effect in dense matter created in the collision?

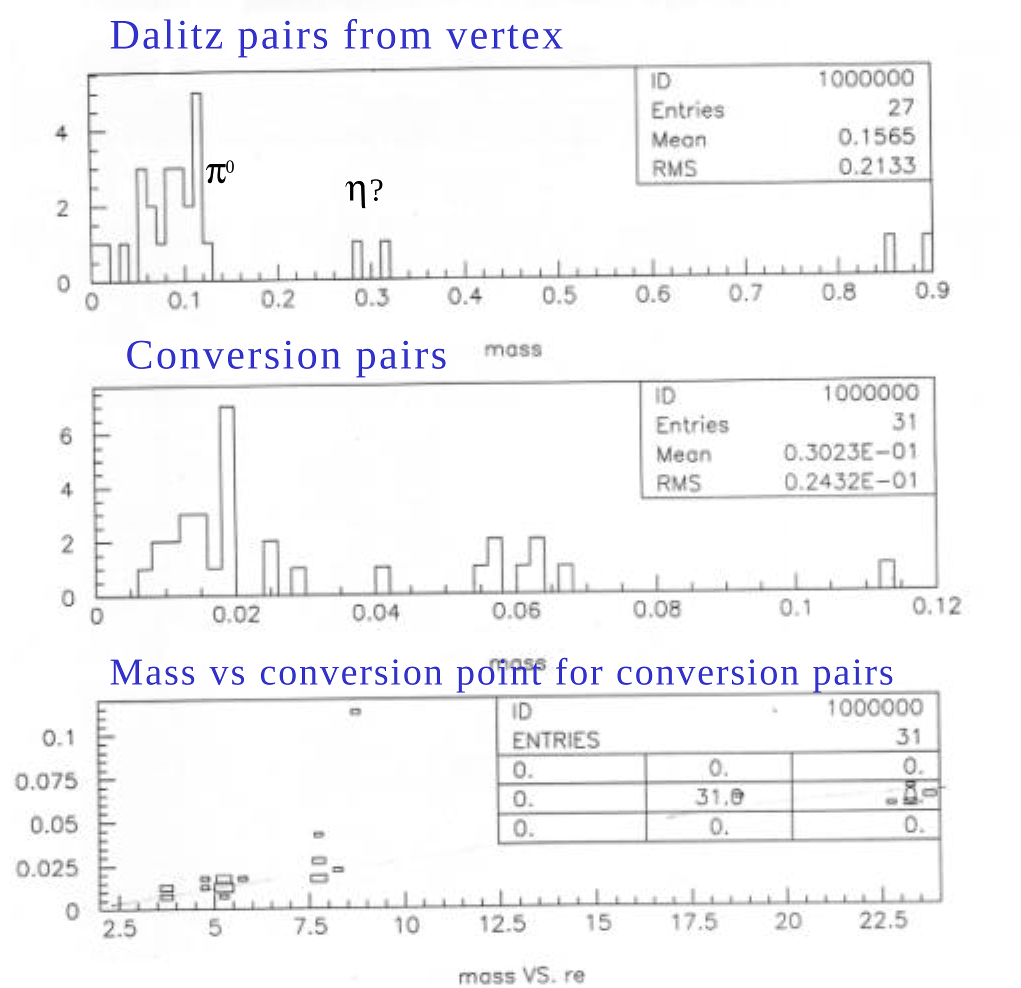
In real world, it is more complicated

- The left figures are again old PISA simulation results. It shows mass distribution of e+e- pairs in 4342 central Au+Au events and in mixed events. Although an excess is visible at low mass region, the peak is not as sharp as it should be
- The yield of the excess is about 60, or 0.014 pairs per events



Causes of broader low mass peak

- Part of the broader peak is that Dalitz simulation was incorrect. In VRDC data, we should see much narrower peak near mass 0, with S/B ratio much better than 10
- Another effect, shown in the lower two panels, is more subtle and interesting. As we assume that the tracks come from the vertex in momentum reconstruction, there is a correlation between the reconstructed mass and conversion point for gamma conversion.



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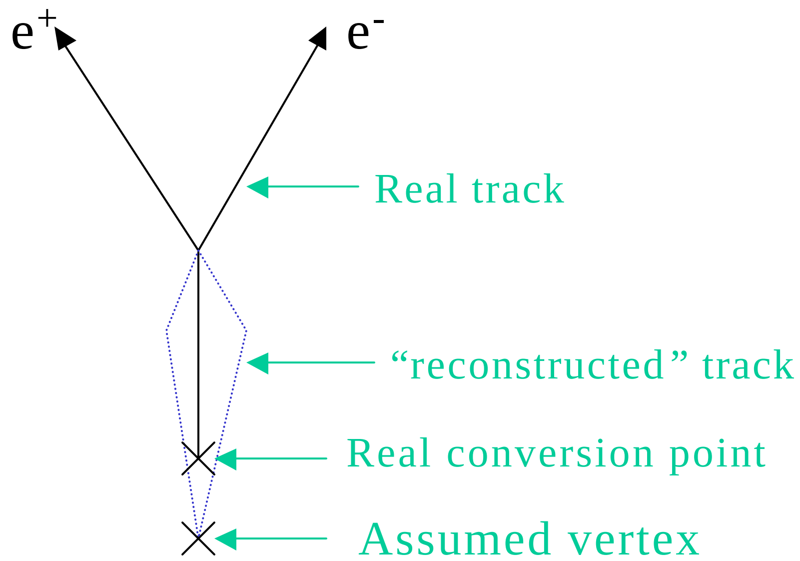
How conversion pairs “acquire” mass?

- The reason that “zero mass” conversion pair acquire mass by momentum reconstruction with assumed vertex position can be schematically understood, as shown in the left figure.
- We have to understand this effect for the analysis of low mass peak
- This effect can be used to isolate (at least part of) conversion pairs from Dalitz
- The interpretation shown in the left implies that the reconstructed e^+-vertex-e^- plane of the conversion pair is roughly perpendicular to the field axis of the magnet. This can also be used to isolate the conversion pair.
- Another implication is that reconstructed electron pt distributions from conversions are different from that of Dalitz. This also need to be studied.
- In principle, the effect should not depends on multiplicity. Thus, peripheral events can be used as a reference.
- The mass shift effect, and the feasibility to use the effect in data analysis should, of course, be studied by a full Monte Carlo in VRDC.

Pair reconstruction with displaced vertex for zero mass pair



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Conclusions and Outlook

- Dalitz and conversion pair is the major source of electrons. Thus it is vital to understand those processes in PHENIX first, before attacking more interesting measurement with electrons.
- It seems feasible to identify and to measure Dalitz and conversion pairs in PHENIX, even in the central Au+Au collision. (Need to be verified in VRDC)
- Once identified, the pairs can be used to study detector response, eID efficiency etc.
- It can also be used to measure inclusive photons. The measurement is complimentary to that by EMCAL.
- The shape of the mass distribution can be used to constrain π^0/η ratio
- There is a non-trivial detector effect to the conversion pairs. The effect need to be studied in Monte Carlo, as well as in the data itself (in peripheral events). The effect, mass shift and the induced angular distribution of the pair, can be used to separate the conversion pairs from Dalitz.
- More quantitative study is needed by using a large full simulation samples from VRDC.